Big Glass for a Big Laser

THE National Ignition Facility (NIF), the largest, most energetic laser in the world—with 60 times more energy than any laser in existence—will be coming on line at Livermore in the next few years. In this laser, energy will be stored in special glass and later extracted as high-power optical pulses. High-energy lasers such as NIF need large pieces of optical-quality glass—and lots of them—to operate as designed. NIF will be about the size of a football stadium and will require more than 3,000 pieces of laser glass, each about 1 meter long, 0.5 meter wide, and 4 centimeters thick.

A revolutionary process developed by Lawrence Livermore and two industrial partners produces meter-size plates of laser glass at a rate 20 times faster and 5 times cheaper than is possible with the previous technology, and the glass itself has 2 to 3 times better optical quality. This work is the culmination of a 6-year research and development project between Livermore and the two leading (and competing) laser glass producers, Schott Glass Technologies of Duryea, Pennsylvania, and Hoya Corporation USA of Fremont, California. Physical chemist Jack Campbell of Livermore led this team.

The Continuous Laser Glass Melting Process developed by the collaboration replaces the only other way to manufacture large pieces of laser glass—the batch method, a one-at-a-time process that produces at most three pieces of glass per week. Not only is this method too slow to meet the demands of NIF, but it is also more expensive, and the optical quality of the glass is not consistent. Practically speaking, continuous glass melting is the only method that can be used to produce the large quantity and high quality of laser glass necessary for NIF. Without this technology, it would be extremely difficult to build a huge solid-state laser such as NIF.

"Developing this process was extremely difficult technically," says Campbell. "In fact, we had a saying, 'laser glass knows no friends,' to describe our frustrations. Now that the process has worked out successfully, frustration has given way to pride. But believe me, there were many anxious moments."

A River of Glass

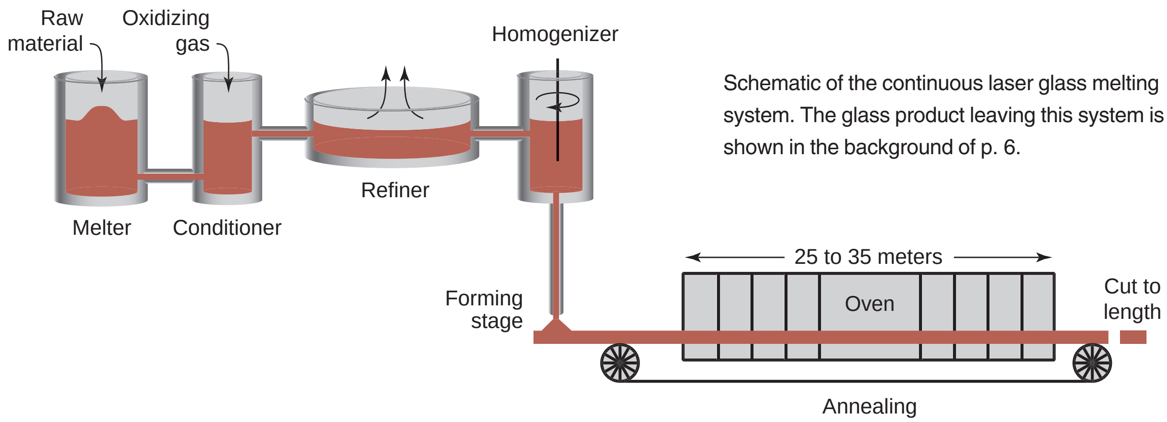
The Continuous Laser Glass Melting Process, shown schematically on the next page, converts high-purity, powdered raw materials into one continuously moving strip of high-optical-quality laser glass. Plates of laser glass are then cut from the end of the strip as it leaves the production system.

The laser glass melting process requires seven operations carried out in separate vessels. The vessels are interconnected to make the process continuous. The first process unit is designed to mix and dry the high-purity raw materials with minimal contamination.

The second unit is the melter system, which dissolves the powdered raw materials into a pool of molten glass and mixes these ingredients using convection currents.The melter consists of custom-designed, high-purity refractory materials and uses a proprietary electrical heating system.

All units beyond the melter are lined with high-purity platinum, as are the interconnecting pipes. Platinum is required to achieve the fine-scale (parts-per-million) optical homogeneity necessary

Livermore developers of the Continuous Laser Glass Melting Process are (left to right) Paul Ehrmann, William Steele, Charles Thorsness, Michael Riley, Tayyab Suratwala, and Jack Campbell. The system was developed in partnership with Koji Suzuki, Kohei Yamamoto, Ryo Konta, Kunio Takeuchi, and Julie Storms of Hoya Corporation USA and Steve Krenitsky, Joe Cimino, Hardy Pankratz, Michael Timms, Dave Sapak, Ed Vozenilek, Joseph Hayden, and Alfred Thorne of Schott Glass Technologies.



Schematic of the continuous laser glass melting system. The glass product leaving this system is shown in the background of p. 6.

for laser applications. However, the platinum can contaminate the glass with microscopic metallic inclusions. When a high-power laser beam hits an inclusion, the beam causes it to vaporize, generating small fractures within the glass. To overcome this problem, the team developed a unique conditioner unit that uses oxygen and chlorine to remove platinum inclusions as well as any residual water. The conditioner unit is perhaps the most complex part in the whole system.

The glass from the conditioner next moves to a refiner section, where bubbles are removed using a combination of high temperature and proprietary additives. From here, the glass enters the homogenizing unit, where it is thoroughly mixed to achieve the one-part-per-million chemical uniformity required to meet optical homogeneity specifications. Finally, molten glass flows through a platinum tube to a mold, where it is formed into one continuously moving strip about 5 to 8 centimeters thick, 0.5 meter wide, and nearly 30 meters long. The glass strip passes through a custom-designed annealing oven where it is gradually cooled from more than 600°C to room temperature. Annealing the laser glass strip is difficult because of the size of the strip and the unusually high thermal expansion and low inherent strength of the glass. Laser glass is five times more sensitive to fracture by thermal shock than most other optical glasses.

Older Process Not Adequate

Neodymium-doped phosphate laser glass can be manufactured by either the batch method, a one-at-a-time melting process, or this new continuous melting method. Schott and Hoya are the only companies in the world making meter-size plates of phosphate laser glass, either by a continuous or discontinuous process. Thus, the only competitor for the new process is the old, discontinuous technology for producing laser glass.

The former technology, which has been used for over 25 years, involves first melting raw materials in a refractory vessel and then manually transferring the melt to a second platinum-lined vessel. Finally, the pieces of glass are individually cast in a large mold. The entire operation is repeated for every piece of glass. Product quality can vary from one melt to the next simply because of small, run-to-run variations in processing conditions. The cost—more than $5,000 per liter of glass—is also high.

Continuous glass melting, however, has a much greater production rate of 70 to 300 pieces per week, and little, if any, measurable variation in glass properties from one glass plate to the next. Plus, the cost is less than $1,000 per liter.

NIF and Beyond

Hoya and Schott will also be manufacturing large pieces of glass using the continuous melting method for the Laser Megajoule (LMJ) in France. The LMJ's requirements are similar to those of NIF.

Both Hoya and Schott are applying several new technologies developed for the Continuous Laser Glass Melting Process to the manufacture of other optical glasses. Most notably, some of this technology is being used to manufacture the most common optical glass, BK-7, in large sizes. BK-7 is commonly used to manufacture optics for cameras, binoculars, and precision optical instruments. Other aspects of the process are being used to improve the manufacture of glass used in digital cameras, hard-disk-drive substrates, liquid crystal displays, projector lenses, and telecommunication devices.

"The success of this venture is illustrated by the fact that neither company is willing to openly discuss the details of the other applications for the new technology," says Campbell. "The bottom line here is that everyone is a winner from this partnership. NIF gets the laser glass it needs, and our industrial partners get a technology that is a springboard to new glass products."

—Katie Walter

Key Words: Continuous Laser Glass Melting Process, National Ignition Facility (NIF), neodymium-doped phosphate laser glass, platinum inclusions, R&D 100 Award.

For further information contact Jack Campbell (925) 422-6497 (campbell12@llnl.gov).